Linda C. Schaffner

- **Associate Professor of Marine Science**
- **B.A., Drew University**
- **M.A., Ph.D., College of William and Mary**

Email: linda@vims.edu
Office: Maury Hall 207
Phone: (804) 684-7366, 7373

Research Interests

My research program focuses on the ecology of benthic systems and benthic processes of estuarine and coastal ecosystems. Within this context and working together with my students and staff, I have developed and pursued a number of major research themes. We are interested in how natural processes and anthropogenic alterations of coastal ecosystems influence the structure and function of benthic communities, including meiofauna, macrofauna and associated nekton, via processes such as disturbance (mortality) and recruitment. Important factors we have considered include salinity, sediment type and transport regime, eutrophication, hypoxia and sediment contamination. We also are interested in the factors that regulate the productivity of estuarine food webs, such as hypoxia, benthic-pelagic coupling and the population dynamics of estuarine species, especially polychaetes. Much of our research has been interdisciplinary, especially my investigations of organism-sediment-flow interactions and implications of these interactions for the transport, fate and effects of particles, organic matter, nutrients and contaminants in benthic systems. I will soon begin studies of benthic boundary layer processes and organism-sediment-flow interactions using a real-time benthic observing system to gain insight into the timing and magnitude of events taking place at the sediment-water interface, and the real time responses of benthic organisms to those events. I will be assessing the relative importance of resistance to stressors by individuals versus resilience to disturbance processes as manifested primarily at the population level. My studies have taken me to estuarine and coastal ecosystems throughout the U.S. and Europe, including the Chesapeake Bay, Gulf of Mexico, Long Island Sound, Baltic Sea, Andaman Sea, Gulf of Thailand, East China Sea and coastal Korea. In recent years I have become increasingly interested in how society, science and economics interact to influence resource management, science policy and funding for science and science and math education.

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Current Projects

- Collaborative Research: A Real-Time and Rapid Response Observing System for the Study of Physical and Biological Controls on Muddy Seabed Deposition, Reworking and Resuspension. Funded by National Science Foundation.
- An Integrated Approach to Assess the Effects of Watershed Activities on Benthic Community Structure and Function. Funded by Strategic Environmental Research and Development Program (SERDP)

- Research Experience for Undergraduates (REU) at the Virginia Institute of Marine Science. Funded by National Science Foundation.
- Hall-Bonner Program for Minority Scholars in the Ocean Sciences. Funded by National Science Foundation.

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Selected Publications

Lim, Hyun-Sig, R. J. Diaz, Hong, Jae-Sang and **L. C. Schaffner**. Hypoxia and benthic community recovery in Korean coastal waters. (Marine Pollution Bulletin, in press)

Hinchey, E. K., **L. C. Schaffner**, L. Batte, C. Hoar and B. Vogt. 2005. Effects of sediment burial on juvenile and adult benthic invertebrates of estuaries. Hydrobiologia 00:1-14 (in press).

Hinchey, E.K. and **L. C. Schaffner.** 2005. An evaluation of electrode insertion techniques for measurement of sediment redox potential in estuarine sediments. Chemosphere 59:703-710.

Dellapenna, T. M., S. A. Kuehl and **L. C. Schaffner**. 2003. Ephemeral deposition, sea-bed mixing and fine-scale strata formation in the York River estuary, Chesapeake Bay. Estuarine, Coastal and Shelf Science 58(3): 621-643.

Sagasti, A., J. E. Duffy, and L. C. Schaffner. 2003. Effects of stress on recruitment: estuarine epifauna recruit depsite hypoxic episodes. Marine Biology 142:111-122.

Thompson, M. L. and **L. C. Schaffner**. 2001. Population biology and secondary production of the suspension feeding polychaete *Chaetopterus variopedatus:* implications for benthic-pelagic coupling in lower Chesapeake Bay. Limnology and Oceanography 46: 1899-1907.

Schaffner, L. C., T. M. Dellapenna, E. K. Hinchey, C. T. Friedrichs, M. Thompson Neubauer, M. E. Smith and S. A. Kuehl. 2001. Physical energy regimes, seabed dynamics and organism-sediment interactions along an estuarine gradient. pp. 161-182 in J. Y. Aller, S. A. Woodin and R. C. Aller (eds.) Organism-Sediment Interactions. University of South Carolina Press, Columbia, SC.

Sagasti, A., **L. C. Schaffner** and J. E. Duffy. 2001. Effects of periodic hypoxia on mortality, feeding and predation in an estuarine epifaunal community. Jour. Exp. Mar. Biol. Ecol. 258: 257-283.

Sagasti, A., **L. C. Schaffner** and J. E. Duffy. 2000. Epifaunal communities thrive in an estuary with hypoxic episodes. Estuaries 23: 474-448.

Thompson, M. T. and **L. C. Schaffner**. 2000. Demography of the polychaete *Chaetopterus pergamentaceus* within the lower Chesapeake Bay and relationships to environmental gradients. Bulletin of Marine Science 67: 209-219.

Dellapenna, T. M., S. A. Kuehl and **L. C. Schaffner**. 1998. Seabed mixing and particle residence times in biologically and physically dominated estuarine systems: a comparison of lower Chesapeake Bay and the York River subestuary. Est. Coast. Shelf Sci. 46: 777-795.

Kane-Driscoll, S. B., **L. C. Schaffner** and R. M. Dickhut. 1998. Toxicokinetics of fluoranthene to the amphipod, *Leptocheirus plumulosus*, in water-only and sediment exposures. Marine Environmental Research 45: 269-284.

Schaffner, L. C., R. M. Dickhut, S. Mitra, P. W. Lay and C. Brouwer-Riel. 1997. Effects of physical chemistry and bioturbation by estuarine macrofauna on the transport of hydrophobic organic contaminants in the benthos. Environ. Sci. Technol. 31: 3120-3125.

Wright, L. D., **L. C. Schaffner**, and J. P.-Y. Maa. 1997. Biological mediation of bottom boundary layer processes and sediment suspension in the lower Chesapeake Bay. Marine Geology 141: 27-50.

Weisburg, S. B., J. A. Ranasinghe, D. M. Dauer, **L. C. Schaffner**, R. J. Diaz and J. B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. Estuaries 20: 149-158.

Mayer, M. M., **L. C. Schaffner** and W. M. Kemp. 1995. Nitrification potentials of benthic macrofaunal tubes and burrow walls: effects of sediment NH4+ and animal irrigation behavior. Marine Ecology Progress Series 121: 157-169.

Seitz, R. D. and **L. C. Schaffner**. 1995. Population ecology and secondary production of the polychaete *Loimia medusa* (Terebellidae). Marine Biology 121: 701-711.

Diaz, R. J. and **L. C. Schaffner.** 1990. The functional role of estuarine benthos. pp. 25-56 in M. Haire and E. C. Krome (eds.), Perspectives on the Chesapeake Bay, 1990. Advances in Estuarine Science. Chesapeake Bay Program, Chesapeake Research Consortium Publication #CBP/TRS41/90.

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Current Students

- David Gillett. Ph.D. The influence of habitat degradation on benthic secondary production and trophic transfer efficiency in shallow, unvegetated areas
- William Metcalfe, M.S. Meiofauna abundance and distribution in Chesapeake Bay: Relationships with eutrophication, sediment toxicity and macrofauna
- Erin Morgan, W&M undergraduate. Factors influencing benthic community integrity in shallow subtidal regions of a highly urbanized estuary.
- Treda Smith, Ph.D. Developing an ecological basis for indicators and biocriteria in estuarine waters.

Past Students - Graduate Program

- Elizabeth K. Hinchey, Ph.D. 2002. Physical disturbance effects on benthic community structure and function along an estuarine gradient. Recipient of *Craig Smith Award* (1999), *Dean's Prize for Advancement of Women in Science* (2001) and *Thatcher Prize* (2003)
- Michelle Horvath, M.S.1997. Effects of epibenthic predators and macrofauna on sediment resuspension and bioturbation.
- Patrick Lay, Ph.D. 1996. Direct effects of macrofauna on transport of organic contaminants to demersal fish.
- Alessandra Sagasti, Ph.D. 2000, Ecology of fouling communities in the York River ecosystem: interacting effects of environmental variation and biotic interactions on community structure and function. Recipient of *John and Marilyn Zeigler Student Achievement Award* (1999) and *Dean's Prize for Advancement of Women in Marine Science* (1999) and *Best Ph.D. Oral Presentation, Atlantic Estuarine Research Society* (co-advisor with Emmett Duffy)
- Michelle L.Thompson Neubauer, Ph.D. 2000, Benthic-pelagic coupling in lower Chesapeake Bay: effects of a benthic suspension feeding polychaete, *Chaetopterus pergamentaceus (Chaetopterus cf. variopedatus*, sensu Enders 1909). Recipient of *Mathew Fontaine Maury Student Fellowship Award* (1999) and *Best Student Poster Award, International Estuarine Research Federation Conference '99, New Orleans, LA*
- Rochelle Seitz, M.S. 1991. Population biology of the polychaete *Loimia medusa* (Savigny) on a tidal sand flat of the York River.
- Bruce Vogt, M. S. Student, Sublethal effects of sediment-associated contaminants on the burrowing behavior of the amphipod, *Leptocheirus plumulosus*

Past Students - Undergraduates and High School

- Lauren Batte, Department of Biology, The College of William and Mary, B.S. with High Honors, 2001.
- Undergraduates who have done internships in my laboratory: William O'Connell (1989), Doug Gantt (1990), Sharon Williams (1991), Michelle Rudoy and George Anderson (1992), Rebecca Born (1993), Simone Brooks (1994), Sam Jones and Charles Shimooka (1995), Alvaro Dompe (1996), Jennifer Lindsey and Allison Castellan (1998), Tara Spitzer and Scott Lundin (1999), Stephanie Babb and Christine Tallamy (2000), Patrice Longshaw and Barbara Garcia (2001), Theresa Childress (2002)
- High School students who have done internships in my laboratory in recent years: Jennifer Shontz (1998-99), Benjamin Ritter (1997-98), Kelly Dorgan (1995-97)

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Courses Taught

- MS 502: Coastal and Estuarine Processes and Issues
- MS 572: Estuarine Benthic Processes
- MS 503: Biological Oceanography
- MS 510: Marine and Freshwater Invertebrates
- MS 647: Marine Benthos
- MS 698: Special Topics - History of Benthic Ecology

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Awards

- 2005 - Dean's Prize for Advancement of Women in Science
- 2003 - Outstanding Faculty Award, State Council of Higher Education of Virginia
- 2001 - The Thomas Jefferson Teaching Award, College of William and Mary
- 1994 - Outstanding Teaching Award, School of Marine Science, College of William and Mary

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Positions of Distinction

- Past President, Estuarine Research Federation (2005-2007)
- President, Estuarine Research Federation (2003-2005)
- Secretary, Council of Scientific Society Presidents (2004-2005)
- Estuarine Research Federation President Elect (2001-2003)
- Estuarine Research Federation Governing Board, Secretary (1999-2001)
- Estuarine Research Federation Governing Board, Member-at-Large (1997-1999)
- Estuarine Research Federation Education Committee (1997- present)
- Associate Editor, Estuaries, 1998-2001

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Professional Memberships

- Estuarine Research Federation (ERF)
- American Society of Limnology and Oceanography (ASLO)
- American Geophysical Union (AGU)

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Biological Sciences / VIMS
P.O. Box 1346, Gloucester Pt., VA 23062-1346, USA
Telephone: 804-684-7344; FAX: 804-684-7293

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Written Testimony of
Linda C. Schaffner, Ph.D.
Associate Professor, Virginia Institute of Marine Science

"Progress in Safeguarding the Chesapeake Bay"
Committee on Government Reform
U.S. House of Representatives
Field Hearing, Hampton, Virginia
August 20, 2004

Chairman Davis, Congressman Schrock, and Members of the Committee, my name is Linda Schaffner. I am an Associate Professor of the School of Marine Science, College of William and Mary and the Virginia Institute of Marine Science (VIMS). I also serve as the President of the Estuarine Research Federation (ERF), an international scientific society with a membership of over 2000 scientists, educators, and managers who are committed to the acquisition and application of sound scientific knowledge to sustain the integrity of estuarine and coastal systems. Thank you for inviting me to speak to you today.

I will begin by diagnosing the current health of the Chesapeake Bay estuarine ecosystem based on the many indicators available. I also want to comment on the importance of monitoring and modeling as tools in the scientific toolbox and the importance of science-informed management in the Chesapeake Bay restoration efforts. Finally, I will reflect on what is needed to move us forward towards our goal of a healthy, sustainable Chesapeake Bay.

An Estuary Under Stress

The Chesapeake Bay is one of the world's largest, most diverse and productive estuarine systems. Its watershed is home to a significant percentage of the U.S. population. We all understand the key role the Bay has played in supporting bountiful harvests of commercial and ecologically valuable species, such as crabs, oysters and fish. We also recognize the Bay's importance in support of transportation and industry and the need for its ports and harbors. Tourists and recreational fishermen enjoy the Bay and contribute to local economies. Many of us value the Bay for its natural beauty. In addition, scientific research has highlighted the important ecological services provided by the Chesapeake Bay and other estuaries. Unfortunately, the very features that promote high productivity and facilitate its use, make the estuary highly vulnerable to human effects, which in turn jeopardizes these goods and services.

Just four months ago the U.S. Commission on Ocean Policy[1] (USCOP) released its draft findings and recommendations for a coordinated and comprehensive national ocean and

coastal policy. The USCOP found abundant evidence of degraded water quality, depleted fishery resources, and vanishing wetlands throughout the Nation's coastal and estuarine areas and determined that these problems require urgent attention. In a study released in 2003, the Pew Oceans Commission[2] independently reached a very similar conclusion that our oceans and coastal systems are in severe distress. I can assure you that we are not alone in our concerns about the state of our estuary.

Human alteration of the Chesapeake and its watershed began hundreds of years ago, but the most significant activities have been during our lifetime. When I first arrived to the Bay community as a graduate student in 1976, a favorite late fall activity was roasting oysters over an open fire with a group of friends on a Saturday night. Over-harvest, disease, and habitat alteration have now resulted in the near demise of the native oyster. The oysters I buy in my local grocery store come from the Gulf of Mexico or the west coast. The once clear, shallow waters of the Bay are now turbid, and the submerged grasses that once flourished there, providing critical habitat for juvenile fishes and crabs, are 60% less abundant than they were 40 to 50 years ago[3]. Each summer, a blanket of water that is devoid of essential oxygen smothers communities of small bottom dwelling (benthic) invertebrates throughout the deeper waters of the Bay. This is important because these benthic communities support the Bay's food web and also play a role in helping to cleanse the Bay of excess nitrogen, a key nutrient fueling eutrophication. For 2002, scientists estimated that about 50% of the Chesapeake Bay and 65% of the Maryland tidal waters failed to meet the restoration goals set for these communities.[4]

For most of the indicators we use to gauge the health of the Bay, the available monitorin data allow us to examine trends over only the last few decades, not the last 100 years or more. When we look back even further -- for example, using markers preserved in the accumulated muds of the deep floor of the Bay -- we find evidence of the longer history of human alteration of the Bay's structure and function. This record tells us that sediment loading to the Bay increased when farmers began extensive clearing of the watershed, that the composition of pollutants entering the estuary has changed over time and that a record of increasing hypoxia and anoxia in bottom waters parallels a trend of increasing nutrient fertilization. Just as we expect a doctor to diagnose our health using multiple indicators, these indicators of Bay health lead me to conclude that the Chesapeake Bay is a significantly degraded ecosystem. To continue with the medical analogy, the Bay has cancer, not a common cold.

But, there is always room for more positive thinking. Like many of my colleagues, I have seen evidence of the Chesapeake Bay's resilience -- its natural capacity to recover from disturbances. Each year scientists working in and around the Bay's meadows of submerged aquatic vegetation (SAV) report the presence of grass seedlings in the deeper waters outside of the existing beds[5]. The production of seeds and subsequent growth of seedlings are examples of the natural processes that help to make populations resilient despite environmental variations. Under present Bay conditions, the grass seedlings generally don t survive the summer due to light limitation caused by eutrophication and suspended sediments. The expansion of SAV meadows in drought years, when reduced freshwater flow reduces the problematic nutrient loadings, and the declines of SAV in wet years, when nutrient loadings tend to increase, gives us insights into what might happen if we could off the "nutrient faucet."

Every year, and especially during the spring, benthic invertebrates -- clams, worms and small shrimp-like creatures called amphipods -- reproduce and send innumerable larvae into the waters of the Bay. If you dredge a channel in the lower Bay, where the water quality is still relatively good, you will see initial colonization of the bottom in only a few weeks, and most of the natural community will be completely restored in only a year or two. Many of these larvae also reach the deepest channels where they settle and grow until the summertime levels of dissolved oxygen in the overlying waters become limiting. While restoration of dissolved oxygen to the deepest bottom waters is considered to be one of the most difficult problems we face, it seems likely that these areas would rapidly recover their productivity if given a chance.

Modeling and Monitoring

Scientists in the estuarine science community, including those working as a part of the Chesapeake Bay Program, have repeatedly demonstrated that the combined use of powerful modeling approaches and good observational data can lead to rapid advances in scientific understanding. The ever-increasing power of today's computers allows us to model the complexities of natural systems in ways that were unthinkable only a decade ago. Models help us to understand how aquatic systems respond to various scenarios, such as variations in rainfall or changes in land use, independent of what is happening at any given time in the "real world." They can be used to forecast future changes in an ecosystem, and to test, for example, whether implementation of specific policies and management strategies will be successful. Conversely, monitoring data document trends in the "real world" and give us a needed reality check for our models. The data obtained via well-designed monitoring programs can be used to constrain the models and to verify model predictions.

Attempts to weigh the relative merits of modeling or monitoring are misguided they are two sides of the same coin. We need both and they should be used in concert to understand and verify where we are in our efforts to restore the Bay. Good communication and exchange of information between monitoring and modeling efforts is essential. Although this needed level of communication may be relatively easily established and maintained when a program is small, it can be considerably more difficult to attain when a program is large or when different agencies are responsible for modeling versus monitoring programs. The current discussions should make everyone more sensitive to the need to maintain good communication and present a consistent overview of the findings of the monitoring and modeling efforts.

The Importance of Science-Informed Management

In its April 2004 draft report, the USCOP called for ecosystem-based management of ocean and coastal resources and recommended that management "... reflect the relationships among all ecosystem components, including human and nonhuman species and the environments in which they live." This has always been a major goal of the Chesapeake Bay Program (CBP), which since its inception has been admired and emulated throughout the U.S., and worldwide, as a model for ecosystem-based management. The CBP, working in partnership with the states and various agencies, has provided both a structural framework and leadership that helped to focus one of the world's strongest estuarine science communities, build well-designed and executed environmental monitoring and modeling programs, create an environmentally-informed public and spearhead new approaches to

environmental policy development and governance. The program has successfully brought scientists, managers, industry and citizens to the table to discuss complex environmental issues and develop strategies for dealing with these issues.

When I met with colleagues at the Virginia Institute of Marine Science earlier this week in preparation for this testimony, they reflected positively on their interactions with the CBP. We agreed that program has done a good job of soliciting science input on the issues, asking scientists to review programs, recommendations and strategies, and practicing science-informed management. When a CBP manager wants something from you, he or she will find you. The CBP program helps to keep us focused. The holistic view that many of us working in the Bay's science community have of the Bay and its ecosystem can be attributed, in my opinion, to the structure and synthesis the CBP has promoted.

I also want to emphasize that academic scientists, many employed at the major state universities around the Bay, have significantly contributed to the success of the CBP objectives. They provide the CBP with unbiased, credible and up-to-date scientific information. The Bay's scientists have led the way in the development of state-of-the-art modeling approaches, experimental approaches in the lab and the field and well-designed monitoring programs to address both the basic and applied questions posed by managers. Many have been exemplary "scientist-citizens," working in service to the Chesapeake Bay Program for the greater good.

Much of the focus today will be on the funding need to support nutrient reduction in support of efforts to restore the Bay's water quality. I also want to use this opportunity to stress the importance of funding for science research efforts. Much of the research conducted by the Bay's scientists has been supported by funding coming from outside the CBP, via other mission-oriented agencies, such as NOAA, ONR, DoD and USGS, other parts of EPA, and the NSF, which plays a critical role in supporting basic research. A number of recent reports and analyses, including those by the American Association for the Advancement of Science (AAAS), indicate that these agencies could see budget declines of 5 to 10% or more annually over the coming years[6]. In their draft report, the USCOP expressed concern that the federal agencies supporting ocean and estuarine research are, in fact, chronically under-funded. We in the Bay community cannot afford these declines in research support at a time when we face increasingly complex scientific questions and management issues. You, our Members of Congress, can help by voting for increased appropriations for science funding in these agencies. I strongly encourage you to support the doubling of the budget for the National Science Foundation, an authorization that was passed by the 107th Congress and signed into law by the President.

There is no question that achieving the ambitious goal of restoring the Chesapeake Bay to a healthy, sustainable ecosystem will require increased scientific capacity, including:

- utilization of the latest technologies and approaches, such as real-time data collection and observing systems to increase monitoring capacity and ensure the collection of the highest quality data, while improving the cost efficiency
- expansion of monitoring programs to evaluate impacts and guide research, not just in the Bay's main stem, but in the tributaries and extensive shoal areas that remain understudied
- support of basic research that will lead to rapid improvement in the integration and

synthesis of existing and new information using the most advanced techniques and the most powerful modeling approaches this will allow scientists to turn data systems into knowledge systems
- improvement in our ability to integrate across the disciplines of natural science, economics, and social systems, and at larger spatial scales and greater temporal resolution
- improvement in our ability to rapidly and effectively share an ever growing body of knowledge, in order to facilitate wise decisions by all about use of the Bay's resources.

Moving Forward for a Healthy, Sustainable Chesapeake Bay

Recognizing the challenges we face in managing our ocean and coastal resources, the USCOP called for the creation of a new national ocean policy framework, better coordination among federal agencies, a doubling of federal research investments in ocean science, and improved environmental education. All of these recommendations have relevance in our discussion of how to accelerate the restoration and protection of the Chesapeake Bay. Others have or will speak in a more informed way on the specific policies and levels of funding needed to attain the Chesapeake 2000 goals. It is clear that both political will and strengthened financial commitments are necessary. We need the public and all of our elected representatives to recognize the true value of the Chesapeake Bay to the Nation. There is no time like the present for action, particularly for those of us concerned with the future of the Chesapeake Bay.

Notes

1. http://www.oceancommission.gov/
2. http://www.pewoceans.org/
3. Robert Orth and Ken Moore, Virginia Institute of Marine Science, communication on August 16, 2004
4. Llansó, R. J., L. C. Scott and F. S. Kelley. 2003. Chesapeake Bay Water Quality Monitoring Program, Long-term Benthic Monitoring Component Level 1 Comprehensive Report, Prepared by Versar, Inc. for Maryland Department of Natural Resources, September 2003.
5. Robert Orth and Ken Moore, Virginia Institute of Marine Science, communication on August 16, 2004
6. Schaffner, L.C. 2004. Science Advocacy: The 10% Solution. *Estuarine Research Federation Newsletter* 30: 1, 13-14. and additional articles by D.M. Allen, R. Magnien, and J. Bartholomew. Available on the web at: www.erf.org.